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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Lubrication of the Uniflow Engine

Accuracy in Viscosity Determinations

PUBLISHED MONTHLY BY
THE TEXAS COMPANY, U.S.A.
TEXACO PETROLEUM PRODUCTS

Which Came First, The Chicken or the Egg?

MANY cracker box philosophers have wrangled this deep question with no solution—

Here's another one—

Which came first—the lubricating oil or the machine that uses it.

The answer is—it depends.

In the old hit or miss days of lubrication, a machine was erected, and then there was a scurrying around to find an oil that would work on it.

Unfortunately some of this primitive practice exists today.

But on account of the evolution of Lubrication Engineering the old way is passing (and with due modesty we say this) largely through the example set by the alert body of men who comprise the staff of Texaco Lubrication Engineers.

You may be interested to know that often—very often we cooperate with equipment or machine builders, while the children of their brains are still in the blue-print stage.

We give them scientific advice. We tell them the right grade of Texaco Lubricating Oil to use—even before the unit is built.

Our collective experience enables us to do this. We do not have to wait till the machine is in use—and then by "trial and error" find something that will work.

We know in advance.

And so, when we take over the lubrication of a plant or factory, we do not have to fiddle around.

From the very first we give you the proper lubricant, in the right amount, for every bearing, gear or mechanism—prime movers, auxiliaries or machines.

And to the man who is buying or installing a new type of unit, we say: Do not worry or experiment with lubricants—Call on Texaco. It is possible—or better, certain—that we've been all through it—and can tell you just what to use.

There is a Texaco Lubricant for every purpose; and Texaco Lubrication Service will tell you accurately what kind and what amount to use.

Texaco Delivery Service will get the oils to you on time—

We can ship instantly train-load or five-gallon can.

THE TEXAS COMPANY

Texaco Petroleum Products

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Lubrication of the Uniflow Engine

A RECIPROCATING engine with a water rate when operating either condensing or non-condensing lower than that of a turbine of equivalent power up to 500 K. W.—a reciprocating engine which has a very much flattened water rate curve over wide load ranges, making it particularly adapted to varying loads! We speak of the uniflow engine. Besides these advantages we may add those of: 1. Simplicity of design and operation; 2. Saving of floor space accomplished through maximum pressure range between admission and release in a single cylinder, and 3. The possibility of high rotative speed through proper design. A specific example of remarkable steam consumption is shown in the results of a test on a 350 H. P. unit using 165 lbs. of steam with 165° superheat, operating at 150 R. P. M. at 25″ vacuum. The size of the cylinder was 23″ x 30″. This unit showed a water rate of 8.9 lbs. per I. H. P.

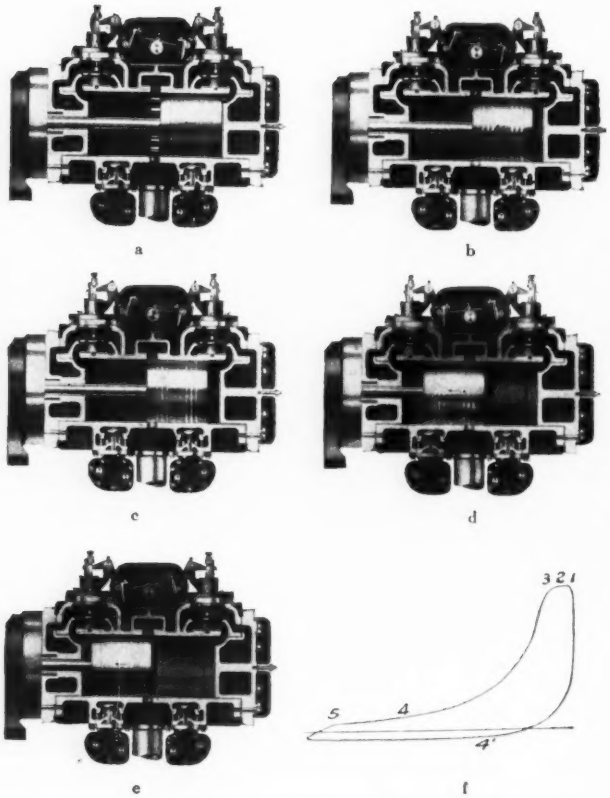
Uniflow Principles

Let us examine the operating principles of the uniflow and see wherein they differ principally from those of the counterflow engine, so that the economy to which we have referred is realized.

In any reciprocating unit, the greater the pressure range between admission and release, the greater will be the theoretical thermal efficiency. The maximum range in the counterflow engine is greatly limited by cylinder condensation and valve leakage; which losses greatly offset the gain caused by increased pressure range. Other factors which influence the maximum range are the type and size of the engine, the number of cylinders and the design of the valve gear.

The application of the uniflow principle has for its object the elimination of one of the causes of the great losses in the reciprocating engine, namely, initial condensation. With the uniflow engine, the steam after passing through steam jacketed heads, enters the cylinders at the ends, and, after cut-off and expansion have taken place, the steam is exhausted through ports arranged around the center of the cylinder, which ports are uncovered by the piston at the end of the stroke. The steam has, consequently, a flow in but one direction; hence the derivation of the phrase "uni-directional flow."

In the counterflow engine, the steam returns on its path at the end of the stroke and is exhausted from the same end of the cylinder at which it entered. In this operation the comparatively cool expanded steam of con-



Courtesy of Skinner Engine Co.

Fig. 1

a. Head End: Admission on dead center. Frame End: Exhaust through central exhaust ports.

b. Head End: Full opening of valve. Frame End: Exhaust through central exhaust ports about to close.

c. Head End: Closing of admission valve and beginning of expansion. Frame End: Commencement of compression caused by piston covering central exhaust ports. In case engine is running non-condensing, lower left-hand auxiliary exhaust valve opens so that compression does not start until the piston has passed this point.

d. Head End: Continuation of Expansion. Frame End: Continuation of compression.

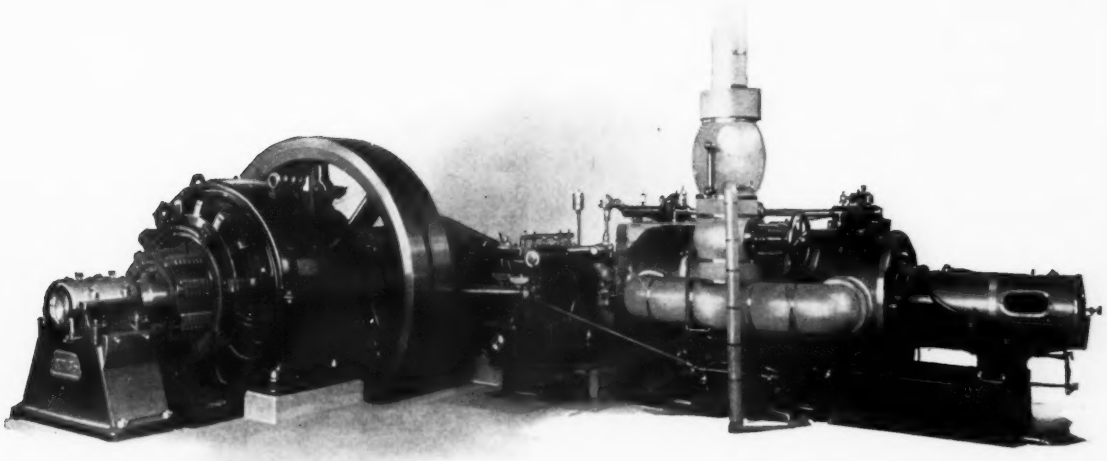
e. Head End: Beginning of exhaust through central exhaust ports. Frame End: Continuation of compression.

f. Indicator Card of engine when operating condensing.

siderable volume washes the cylinder walls and head during 50% to 75% of the return stroke, thereby cooling them to such an extent that the boiler steam, when it is again admitted, is cooled or condensed by coming in contact with the head and clearance spaces of the cylinder which have just been cooled by this expanded steam.

It is this cooling effect that causes what is termed "initial condensation." This is almost entirely eliminated in the uniflow engine as the ends where the steam enters are kept hot and the center or exhaust belt is comparatively cool. In order to reduce this loss by condensation, in the counterflow engine successive stages are resorted to, as in the compound and triple expansion engines. By avoiding the cooling of all clearance surfaces, it is possible in the design of the uniflow cylinder, to obtain in a single cylinder as much expansion, with as good or better economy, as can be obtained in any compound or triple expansion engine.

In Europe practically every steam plant operates condensing. Under these circumstances, compression in the uniflow is made to begin as soon as the piston covers the central exhaust on the return stroke. Compression takes place therefore during 90% of the stroke, which, even with small clearances, does not cause it to mount above the boiler pressure as long as the engine is operated with a fairly good vacuum. If the engine should be operated non-condensing, however, on account of the fact that the steam remaining in the cylinder is at atmospheric pressure instead of under vacuum, the compression would become so excessive as to be detrimental to the engine, unless large clearances were employed. In order to prevent this rise in compression, either when running non-condensing or in case the vacuum should for any reason fail, the builders delay the compression by means of auxiliary exhaust valves placed at approximately half of the stroke.

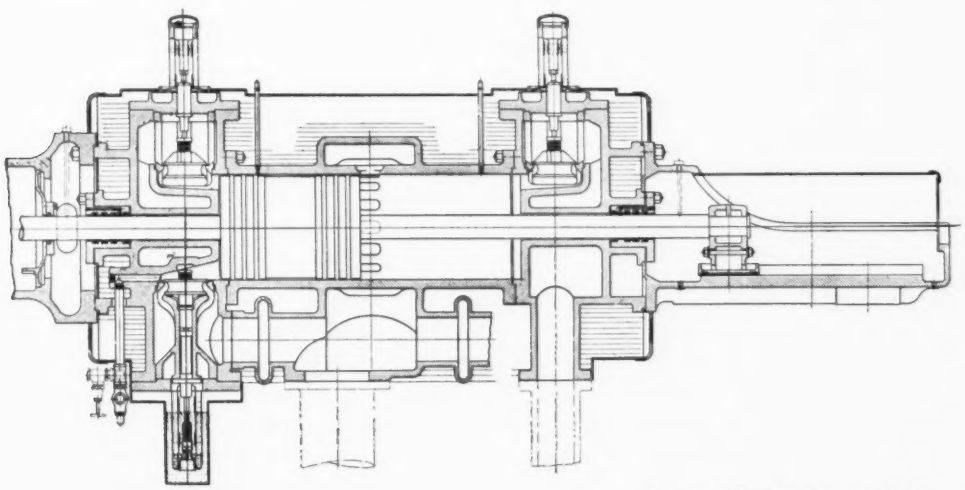


Courtesy of Skinner Engine Co.

Fig. 2.—Typical Uniflow Unit with Side Crank and Floating Piston.

The action is illustrated in Fig. 1-c. Also by the use of snifting or relief valves the cylinders are relieved of excessive compression, as some of the compressed steam is forced into clearance pockets or back into the line. It is obvious that to maintain pure uniflow operating principles, the clearance should be a minimum so that the least possible heated area is washed and consequently cooled by the expanded steam when operating non-condensing.

The accompanying illustrations show the design and action of various types of uniflow engines. Fig. 1 with its caption indicates the difference in action when operating condensing and when operating non-condensing. The illustrations of these engines with floating pistons, Figs. 2 and 3, bring out the fact that the float-



Courtesy of Nordberg Manufacturing Co.

Fig. 3.—Cross-section view of typical Uniflow Engine with floating piston. The oil used in the cylinder and piston rod metallic packing is supplied by a six-feed mechanically operated lubricator. The lay-shaft and outboard bearings are of ring oiling type. The governor, crankpin, cross-head, main bearing, etc., are connected to a central oiling system consisting of an overhead supply tank, with a filter in the basement to which the oil from the points lubricated drains. A gear pump conveys the oil from the filter to the overhead tank. Lower left-hand auxiliary exhaust valve exists at both ends of the cylinder.

ing piston is usually recommended for the larger units, because when using a large piston, scale or other foreign matter, getting under the piston does not have an opportunity of removing itself as it would with a shorter piston. This reasoning applies also to particles of iron getting under the pistons due to lack of lubrication. Uniflow manufacturers do not feel that tail rods are necessary for small or medium sized units.

Due to the extraordinary length of the uniflow cylinder and to the necessity of preventing valve leakage in order to secure economy, the poppet valve is used on nearly all types of uniflow engines. Where the Corliss valve is used, it must be of special design to insure the necessary tightness. At present the uniflow engine finds its largest field of service in requirements up to 500 H. P., but it has been economically used in units up to 2,000 H. P. However, although wonderful economy has been shown by careful attention to details in design, the designer and operator who look for continued success of the uniflow must give due consideration to that factor which, if neglected, will offset much of the good results already accomplished. We refer to lubrication. It is manifest that a realization of the proper economy is impossible without due attention to this item. The importance of the losses which may occur through varying degrees of lubrication is fully realized when it is considered that when this type of engine is contemplated for various industrial conditions, it enters the closest kind of competition.

External Lubrication

The same general principles which are applicable to bearings and slides of other types of equipment hold for the uniflow and in a discussion of this subject should be given complete consideration. This matter was discussed in the December 1921 issue of LUBRICATION.

One rule or law which must be given especial attention by operators and designers, can be stated as follows: The lowest frictional losses are encountered in that bearing which when perfectly lubricated uses a properly refined oil of lowest viscosity. The selection of the proper oil depends on several factors which will now be considered.

Where units are placed so that air circulation is bad and atmospheric temperatures above normal, an oil must be selected which has a viscosity at test temperatures proportionally higher than would normally be used, so that at working temperatures the lubricant will maintain the same viscosity and fluid friction as would be proper under normal conditions.

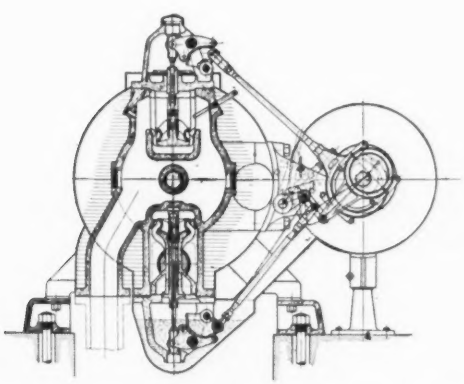
Generally speaking, the larger the clearances per unit of diameter beyond the practical minimum, the more viscous must be the lubricant required for the maintenance of an unbroken oil film. Clearances must be fitted and maintained in accordance with proven best practice.

With perfect lubrication where only fluid friction exists, the bearing parts do not touch the journals or slides, being completely separated by the oil film. In this case the frictional losses are directly due to the internal friction of the lubricant and are entirely independent of the bearing metal and its finish. With solid friction, the loss is greatly dependent upon the smoothness and metal composition of the surfaces. As contingencies may arise which bring the bearings under the laws of semi-lubrication or even solid friction, a high finish and the proper selection of the metals is highly desirable.

Bearing misalignment causes an increased pressure to bear on some parts or in a particular place, necessitating a heavier oil in order to minimize the chance of metal contact. The importance of proper alignment needs no explanation.

In considering the practice of applying the lubricant and particularly in the case of oils which are returned to the bearings, it should be borne in mind that when there is no contamination with lighter blending liquids, the lubricant increases in viscosity with use. The oil in any system should be renewed when it becomes evident through increased frictional temperatures that it is becoming unfit for use on account of increased viscosity or a gradual breaking down.

In bearing design, pressures are of first consideration. At equal speeds for the same bearing metals and identical surface conditions, the greater the pressure per unit of area, the heavier the oil must be to successfully resist being squeezed from the bearing. For strictly fluid friction, which of course we seek to attain, under ordinary pressures the frictional resistance is practically independent of the pressure between the surfaces. Heavier pressures require more viscous oils, and fluid friction increases with viscosity. There is, therefore, a happy medium in bearing design, as it will be noted that excessive pressures mean excessive fluid frictional loss on account of the necessity of using more viscous oils, while if the design is such that unit pressures are below normal this usually means an excessive size of bearing surfaces, again resulting in high fluid frictional losses.



Courtesy of Nordberg Manufacturing Co.

Fig. 4.—Section through valve gear. Attention is called to auxiliary exhaust valve which can be thrown into operation if the engine is working non-condensing. The lower cams of this valve operate in a bath of engine oil.

The question of speed is most important in discussing the selection of the bearing lubricant. The higher the speed of the bearing, the higher the pressure which will be built up in the oil film and consequent resistance to breaking of the film. This increased pressure is due to the pumping action aided by the adhesiveness of the lubricant to the bearing surfaces. This means that as speeds increase oils of less viscosity can be used and still have no metallic contact. Lubricants should be introduced into the bearings at the point of minimum bearing pressure.

Friction losses vary greatly with the method of application. Stream lubrication with positive feed, adequate oil supply, and efficient oil purification, in which it is possible to keep the system free from leaks and other major losses, are recommended above all other methods. If all these features are not present the system, generally speaking, will show some loss of effectiveness in its lubrication. With satisfactory stream lubrication, the main advantages to be expected are: Longer life of bearings due to small or no solid friction, possibility of using oil of lowest viscosity, increased life of oil through decreased abuse and lower oil temperatures, decreased vibration thereby lessening depreciation, and a saving in the labor of attention. Individual systems are satisfactory if the oil supply is copious and a means of continually cleaning the oil is provided. Ring oiling is definite enough but lacks the oil cleaning feature. The prime virtue of the splash system lies in its simplicity but the fact that the supply is not positive and the lubricant unpurified is claimed to detract from its value. Hand feed and drip cups require heavier oils, also maximum labor of attention. They make the oil supply uncertain, are wasteful of oil and lack the advantages gained where a copious oil supply would carry away the frictional heat of the bearings.

Selection of Engine Oil

Specific recommendations to cover the whole field of uniflow engines obviously cannot be made; but in general it can be said that the first consideration is that the oil must be well refined and of the proper viscosity. For hand and drip feeds, oils of 300″ to 500″ Saybolt viscosity at 100° F. are found satisfactory. For stream lubrication, oils having a viscosity of 150″ to 200″ Saybolt at 100° F. should serve well. The oil should be particularly free from emulsifying tendencies if the presence of water in the oil is a possibility. Specifications of flash point and fire point are absolutely worthless in measuring lubricating value. Pour test specifications are very rarely of value in this service as the oils are seldom exposed to very low temperatures. Gravity may indi-

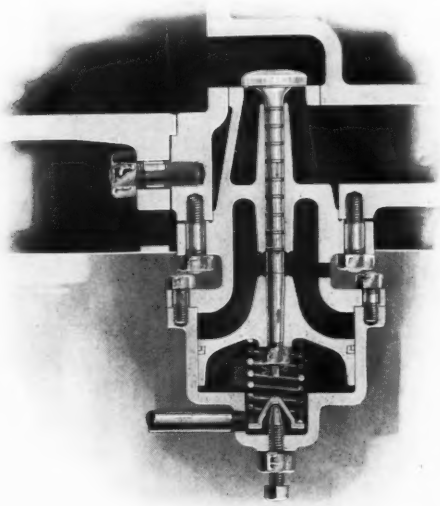
cate to a slight degree the ability of the oil to separate from water but when considering this action the emulsion test results are more important by far than the gravity indication.

For other methods of application, the selection of the proper lubricant will be dependent upon the varying conditions of design and operation but the specifications will lie between the extremes named in the above paragraph.

The Uniflow Valves and Cylinders

In the June 1921 number of LUBRICATION there appeared a comprehensive article on general cylinder lubrication. It is therefore our object to discuss here only those features peculiar to the uniflow engine.

In analyzing uniflow engine cylinder lubrication there are factors which deserve our attention as being uncommon and generally non-existent in the counterflow. These factors involve length of cylinder, weight of piston, steam conditions, piston clearances and bearing pressures, steam jacketing, oil distribution, results of excessive consumption, rod and packing lubrication. The cylinders of uniflow engines are longer than those of the counterflow of the same stroke. This is due to the fact that the piston is only shorter than the stroke by the amount of travel necessary to uncover the exhaust ports at the end of the stroke. The unusual length of the cylinder gives increased areas wiped by the piston, thus demanding an oil that spreads consistently and well. This also results in increased oil consumption over that of the counterflow of equal bore and stroke, operating under identical steam conditions.



Courtesy of Ames Iron Works

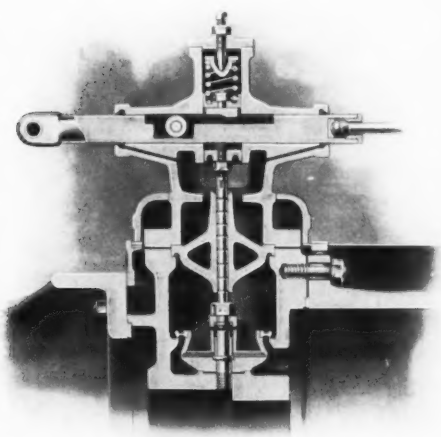
Fig. 5.—Section of typical auxiliary by-pass valve. This valve operates automatically by means of the vacuum in the exhaust belt. If the vacuum is broken or the engine is running non-condensing, the valve automatically is opened.

The increased length of the piston as described in the preceding paragraph brings attention to its increased weight, which is considerable in spite of designs to make it a minimum. The usual uniflow piston incorporates from four to six piston rings. Ordinarily, in the smaller sizes, the piston rides on the cylinder walls, which design gives a bearing pressure of four to six pounds per square inch of projected area. This, of course, does not produce a difficult condition to lubricate. If, however, a contingency should arise whereby the weight of the piston is carried on the rings, the pressure between the rings and the cylinder walls increases abnormally. This produces a difficult condition to lubricate inasmuch as the metals used in manufacture do not permit of high running bearing pressures. Theoretically, trouble will be experienced when this pressure exceeds 100 pounds per square inch with a piston surface speed of 200 feet per minute and when using an oil which is ordinarily of proper grade. With lower speeds, there will be trouble before this pressure is reached.

Considering the selection of the oil from the standpoint of steam pressures, temperatures and quality, it will be noted that a heavier oil, with compounding, will have to be selected for the uniflow than for the counterflow operating with similar steam conditions. The increased viscosity is necessary since continued high temperatures prevail in the uniflow at the ends of the cylinder, while corresponding parts of the counterflow are cooled by the washing of the exhaust steam. As the expanded steam passes out of the center in the uniflow and all of the expansion takes place in one cylinder, the cylinder walls at the middle of the cylinder are continually washed by the wet steam. This necessitates sufficient compounding to satisfy

this condition in order to get proper lubrication, but the compounding should be kept at a minimum consistent with good practice for two reasons: First: when the animal oil used for compounding is exposed to the high temperatures at the ends of the cylinder, there is a tendency to form acids through decomposition, and there is a possibility of the acids attacking the cylinder wall finish. Second: where the condensate is returned to the boilers or used for ice making or in a heating system, the difficulty of oil separation from the exhaust steam is proportionately increased with increase of compounding percentages. There is, therefore, a correct amount of compounding suitable for each operating condition, but in general this amount does not exceed 8% for the best lubricating results, even with a large percentage of moisture in the throttle steam. Due to the maintained high temperature in parts of the cylinder there exists a condition conducive to carbonization of excessive or poorly refined oil so that the ability of the oil to withstand carbonization at the working temperatures must be well considered in selecting the oil.

Proper running clearances between the piston and the cylinder walls can not generally be discussed, depending as they do upon local conditions as found in each individual installation. Where uniflow cylinders are bored to the same diameter throughout when cold, the difference in temperature between the parts of the cylinder when hot causes varying running clearances at different parts of the stroke. In some units, this expansion is compensated for by boring the cylinder when cold to diameters that will bring the cylinder to a uniform bore under running temperatures. This greatly simplifies the discussion of clearances. However, when the clearances vary due to unequal expansion and the oil fulfills the function of preventing steam flow past the rings, it must be viscous enough to meet the hardest condition, *i.e.*, at the point of highest pressure and maximum temperature. It is evident that where boring does not compensate for the irregularities of expansion, the uniflow conditions require the use of an oil of heavy body.

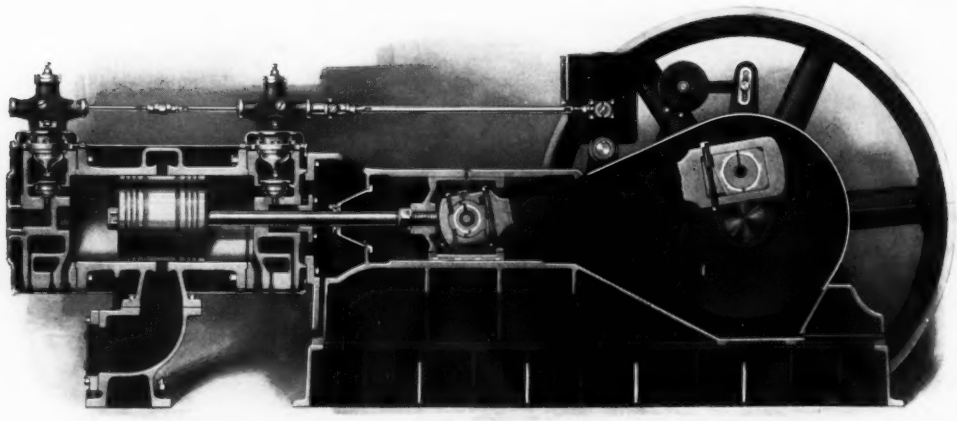


Courtesy of Ames Iron Works

Fig. 6.—Section through admission valve. This valve is lifted from its seat by means of a roller which comes in contact with the lifting cam. The valve is closed by means of a spring in the top of the bonnet.

As previously stated, to maintain high temperatures at the admission ends, these parts are steam jacketed, the general practice being to use throttle steam, the steam passing from the jackets through the valves to the cylinder. This causes a condition which makes it impractical to introduce the oil into the steam line by atomization methods as the jackets act as separators, removing the oil in varying degrees from the steam before it gets to the cylinder. It therefore becomes necessary to introduce the oil directly into the cylinder, depending upon the piston to smear the oil over the cylinder walls, the extent of smearing, of course, depending upon the number and location of the points of introduction of the oil. This condition makes the use of a heavy oil necessary, especially if the number of feeds is small.

In considering the proper number and location of the points of introduction of the oil to the cylinder, it may be said that while these will vary with different installations, that plan whereby the distribution of the oil is most efficient is the best. The minimum number of distribution points is obtained with only two feeds, one at each end at the top of the cylinder. Distribution efficiency, however, will increase with the increase in the number of feeds, and improved results can be obtained by locating these top feeds near the central exhaust belt.



Courtesy of Ames Iron Works

Fig. 7.—Section through typical Uniflow Engine. The cylinders and piston of this engine are lubricated by a mechanical oil pump on the engine frame. One feed from this pump leads to two or more points near the ends of the cylinder, feeding the oil direct to the piston. The other feed leads to the throttle valves and stems. The engine is externally lubricated from a combination filter and reservoir above the engine. From this reservoir the oil is led to the various points to be lubricated. The excess and used oil is collected in the crankpit, from which it is pumped to the filter. In the filter the oil passes through water and a number of baffles so as to remove impurities.

Increased number of feeds does not necessarily mean increased overall consumption. On the other hand, it should mean decreased consumption as a result of better distribution. Satisfactory lubrication should be secured on any unit with six cylinder feeds, one at each mid stroke position at the top of the cylinder with the others lying below them in the same vertical plane at a point from 90° to 120° from the top. Feeding cylinder oil to the walls through the piston and piston rod is a method suggested but not yet adopted. This should give satisfaction if properly developed.

Again, due to the high temperatures maintained at the ends of the cylinder, conditions are conducive to carbonization of the oil remaining on these parts for extended periods. Increased carbon deposits can therefore be expected with excessive increases in oil consumption. Consumption in the uniflow should therefore be limited to the minimum even more closely than in the counterflow where the cylinder walls are alternately heated and cooled.

A separate feed receiving the necessary attention to insure constant supply should be fitted for the piston rod and rod packing at the stuffing box, as it is possible to get unusual running conditions here by unequal expansion, particularly so in the units operating without tailrods. Where crankcase splash is used and bulkheads are fitted with stuffing boxes, the same oil as is used in the crankcase should be used in the bulkhead stuffing boxes. The use of cylinder oil in this box should be avoided, particularly when compounded cylinder oils are used, as the compounding aids in forming emulsions in the crankcase oil. Ordinarily the bulkhead stuffing box oil feed is superfluous, as the main function of the box is to act as a wiper to keep the light oil away from the hot cylinder head.

Slide valves can be used on the smaller uniflow units but Corliss and poppet valves are used in the larger units on account of the length of the cylinders and the consequent distance between admission ports. The higher bearing pressure of the slide valve and Corliss valve necessitates the application of fairly liberal feeds. The poppet valves, on the contrary, should obtain oil for the lubrication of the stems only in very limited quantities, excessive oil having carbonizing tendencies and causing the valves to stick.

Selection of Cylinder Oil

In the selection of the proper grade of cylinder oil, viscosity should be considered first. The fact that the piston is out of sight and the action takes place under higher tem-

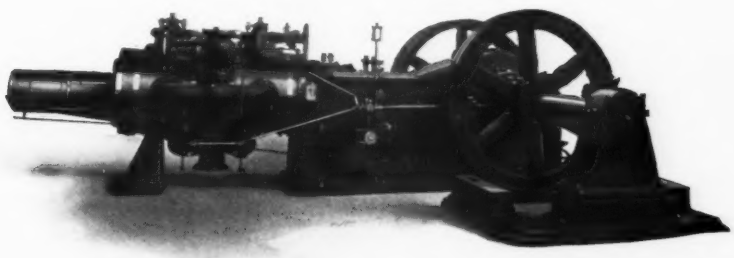
perature conditions, does not eliminate the application of the law which states that an oil should be used which gives practical and efficient lubrication with the lowest viscosity. In the light of conditions as described above and from experience, it is found that a medium bodied cylinder oil of 125″–135″ Saybolt Universal Viscosity at 210° F. is well suited for most units using dry saturated, throttle steam up to approximately 125 lb., while for pressures and temperatures above this, an oil of 150″–160″ Saybolt Universal Viscosity at 210° F. has been found to be well adapted. Unless compounding in the oil is found objectionable from the standpoint of goods manufactured or the use of the exhaust steam for other than manufacturing purposes, an oil is advised with some compounding, but not to exceed 8%.

The oil should be made from stocks that are of such a nature and are so refined as to resist the action of alkaline boiler waters to the greatest extent.

If the flash point and fire points were indications of the carbonizing tendencies of the oil, as some engineers erroneously assume, these specifications would be particularly important in the selection of cylinder oil for use in the uniflow. However, since it is possible for oils of comparatively low flash and fire points to withstand carbonization better than other oils having somewhat higher flash and fire, these points lose much of their importance to the engineer. The proper refinement of good stocks is the main determinant of the carbonizing tendencies of the oil. The proper volatility of a cylinder oil is also of importance. If too volatile, consumption is increased while if not sufficiently volatile the oil may remain in contact with the hot conditions for such a length of time as to carbonize, especially if the oil is not properly refined. Due to the non-importance of cold test and gravity specifications, the man who buys on specifications can afford to be decidedly liberal in the range given on these items.

Conclusions

Naturally there is much to be added to the above relative to the special devices incorporated in the design of the individual manufacturers but since this article aims to discuss the general lubrication of the uniflow, the discussion of special lubrication has been omitted. Where problems arise in connection with the lubrication of special devices, the designer or operator should request the co-operation of some reputable lubricating engineering staff which has had broad experience in lubricating matters. This opportunity for co-operation should be used by the designer, manufacturer and operator of the uniflow that this type of engine may serve to its greatest advantage and continue to further, as it has in the past, the advance of civilization through increased economy.



Courtesy of Skinner Engine Co.

Fig. 8.—Uniflow with center crank and floating piston

Accuracy in Viscosity Determinations

IN a modern routine oil testing laboratory samples are handled and passed down the line with much the same monotonous efficiency as is applied to hogs in a busy packing house.

With hundreds of samples a day to deal with, there is no time for fancy work or personal initiative. The work must be done, and must be done quickly and accurately. In fact, a research worker makes a poor tester, largely because of his original habit of thought and his natural averseness to speed.

In routine testing, the thinking must be done beforehand, and every detail must be laid down in the cold and calculated language of the A. S. T. M. Methods of Test. In the up-to-date oil testing laboratory, measuring instruments such as thermometers, hydrometers, stop watches and graduates, B. S. tubes and volumetric apparatus, must be checked for accuracy and rejected if found not to comply exactly with specifications. Moreover, the arrangement and set-up of the apparatus of test must be carefully thought out with the end in view of facilitating rapid work and eliminating chances of error.

One of the most important routine tests made on lubricating oils is the measurement of viscosity. Not only must the instrument be extremely accurate and well standardized, but the greatest care must be taken to eliminate personal errors and to be sure that the temperature conditions are exactly known. The Saybolt tube itself is a fine example of precision work and if carefully used will keep its original constant for a long time. The actual orifice is the weak spot, and can be damaged in two ways. In the first place, if the film of carbonaceous matter, which is deposited on the walls of the orifice when running oils at 210° F., is not regularly removed by the careful use of a pipe cleaner and a suitable solvent, it becomes so hard that there is a temptation to use a metal reamer. This use of a reamer is absolutely fatal to the accuracy of the tube, as its diameter will be sensibly increased, in spite of the most painstaking precautions.

Another way of damaging the orifice is not so well known as it should be. It is a practice with some testers to stir the oil in the Saybolt tube with a thermometer, and to allow it to remain in the tube if the temperature is not just right for running. The bulb rests on the upper edge of the orifice and the pressure of the hard glass against the comparatively soft metal causes it to burr over in a surprisingly short time, thus causing the tube to run high. This risk can be avoided by placing

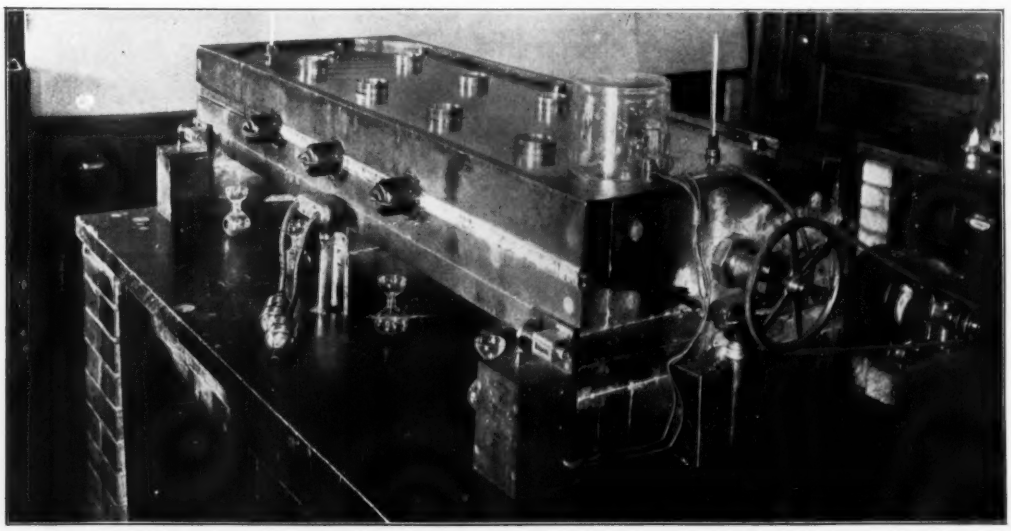


Fig. 1.—View of constant temperature bath for Viscosity Measurements.

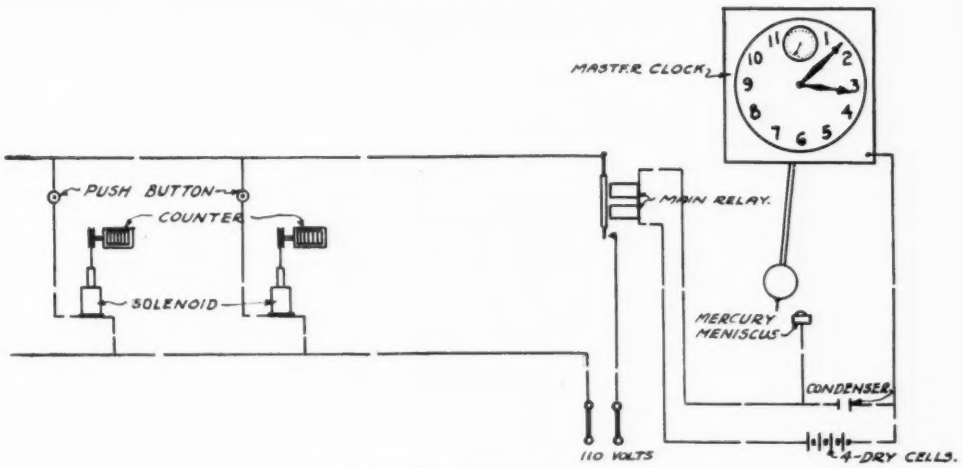


Fig. 2.—Diagram of counter operating mechanism.

at the bottom of the tube over the orifice an open mesh grid on which the bulb of the thermometer can rest. The presence of the grid has been shown to have absolutely no influence on the time of efflux of the oil.

In the accurate measurement of viscosity, very great care must be taken to keep the temperature of both bath and sample at the specified points. The bath must always be at a higher temperature than the sample and the excess varies from ¼° F. to 2° F., depending on the actual temperature of the run, and whether the liquid in the bath is oil or water. The end in view is always to make sure that the temperature of the oil in the tube is that specified and that it remains constant throughout the run. Uncertainty on this point is one of the most fruitful causes of poor checking in viscosity determinations.

As an example of the influence of temperature on the viscosity of an oil, the following figures are quoted:

Temp. of Run	Viscosity	Checks		Mean	Percentage Error Referred to Viscosity at 100° F.
97	334.3	335.0	334.5	334.6	10% High
98	324.5	324.2	323.3	324.0	6.6% High
99	313.7	313.0	314.0	313.6	3.1% High
100	304.3	304.3	.....	304.3	Standard
101	297.0	296.8	296.5	296.8	2.8% Low
102	288.5	287.5	288.5	288.2	6% Low
103	280.5	281.0	280.0	280.5	7.9% Low

From this table it is readily seen that in order to ascertain the viscosity of a 300 second oil to one second, the temperature measurement must be accurate to 1/10° F. To obtain this accuracy a well-controlled thermostatic bath is necessary. How this is more than accomplished in the laboratories of The Texas Company may be of interest to our readers.

The water bath is of soapstone and has provision for eight Saybolt tubes. A vigorous circulation is maintained by stirrers, and the temperature at all points in the bath is practically the same. Heating is by General Electric immersion heaters. There are six of these units, each rated at 750 Watts and they are connected three in series, and then paralleled. The combination is equivalent to an input of 500 Watts. A thermostat of the expansion strip type controls the current relay, and the heating current is either full on or full off. As contact points often stick, a vibrator is so attached as to periodically give a slight vibratory motion to the contact system.

In order to determine the maximum of fluctuation of bath temperature, a test was made with a Beckmann thermometer. This was read over a period of twenty minutes, and the following readings were taken:

Time	Reading	Time	Reading
0	1.665° C.	11	1.675° C.
1	1.680	12	1.685
2	1.675	13	1.670
3	1.685	14	1.665
4	1.685	15	1.660
5	1.665	16	1.665
6	1.675	17	1.660
7	1.680	18	1.660
8	1.680	19	1.685
9	1.680	20	1.680
10	1.660	..	.....

This test showed a maximum variation of 1.685 — 1.660 = .025° C. or .045° F.

As the Saybolt tubes can not take up quickly the temperature differences in the outside bath, the variation in temperature of the oil being tested is much less than that of the bath.

Another great source of error lies in the measurement of time. Stop watches measure to 1/5 second, but they differ more than this amount and the personal factor may cause an error many times the supposed accuracy of the watch. Besides, stop watches get out of order and the error may not be detected. In order to eliminate as much as possible the personal and watch factors, in connection with the bath

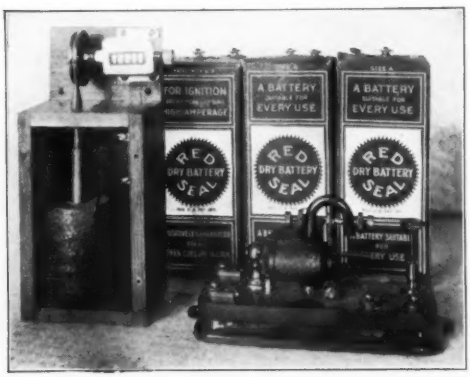


Fig. 3.—Counter, Solenoid, and relay system.

a system of automatic counters has been found both accurate and convenient in actual practice. Incidentally, as stop watches are done away with, a considerable expense for renewals and repairs is also eliminated.

The system derives its time from a Seth Thomas master clock, electrically driven. To the bottom of the pendulum is fitted a platinum wire and a trough of mercury so arranged that the platinum wire cuts through the meniscus.

A circuit, containing a telegraph-type relay, dry cells, the pendulum contact, and the mercury trough is so hooked up as to give an impulse and close the relay contact every second. This contact forms part of a circuit including as many counters as are desired. Each counter is operated by current picked up from the lighting circuit, and locally controlled by a push button switch. The circuit arrangements are as shown in the figure. The actual counting device comprises a stock "Veeder" counter, on the spindle of which is mounted a grooved brass pulley. In the groove lies a gut cord, which conveniently is a violin E string. The lower end of the cord is attached to a soft iron plunger loosely fitting in the axis of a solenoid.

In taking a viscosity the local push button is operated at the instant of pulling the cord. Each impulse of the main relay sends a shot of lighting current through the solenoid and jerks down the cord, thus adding up on the Veeder, the seconds ticked off on the master clock. When the oil reaches the line the operator pushes the button again, thus stopping the counter. The advantages are:

1. The actual elapsed time is read in plain figures, and errors in reading or calculation of the result on a stop watch are avoided.

2. The counter has the accuracy of the master clock, which itself is considerably more accurate than a stop watch.

3. The expense for upkeep is limited to less than a dozen dry cells a year, plus the cost of the operating current picked up from the lighting circuit. The latter is very small and may be reckoned as equal to the power taken by one 50-watt lamp for an installation of 10 counters.

The disadvantage of the system is that readings are only taken to one second; but when it is considered that this accuracy is all that generally is required in routine work and that the operator is sure of the reading, this disadvantage is more than offset by the advantages.

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